

Chemistry Competition

The numbers in parentheses given after the numbers of the problems indicate grades of Russian school. The 8th grade pupils are supposed to solve 1 to 3 problems and 9th to 11th grade pupils solve 2 to 4 problems. The 8th grade is the first year of chemistry in Russian school and 11th grade is the last year before graduation. Solution of the problems meant for senior grades is welcome. The problems for junior grades do not affect the final score.

1. (8–9) Consider a 10.0 g sample of a copper and zinc alloy. If one adds 2.0 g more of zinc, the percentage of zinc in the resulting alloy will be 1.25 times higher than in the initial one. Determine the percentages of zinc and copper in the initial alloy. What will be observed when a powder of this alloy is treated with hydrochloric acid? Write down the reaction equation.

2. (8–9) Lithium is the lightest of metals, its density is 0.534 g/cm^3 . Cadmium is approximately 16 times as heavy as lithium. It has a density of 8.65 g/cm^3 . Using the atomic masses indicated in the Periodic Table of elements, calculate the volume of 1 mole for these metals.

3. (8–9) An organic compound has a molecular mass of 180 atomic mass units. Analysis showed the carbon atoms present in the molecule weigh 72 atomic mass units. Also, the molecule contains hydrogen and oxygen atoms, the number of hydrogen atoms being twice greater than the number of oxygen atoms.

What is the molecular formula of this compound? Write down the balanced equation for the reaction of this compound with oxygen (burning).

4. (9–10) Suppose you have “heavy water” D_2O — this is water containing hydrogen in the form of deuterium (hydrogen isotope with the atomic mass of 2, designated by D). Also, you have any chemical reagents containing no deuterium. Write down the reaction equations needed to synthesize the following compounds:

- 1) LiOD
- 2) D_2SO_4
- 3) DCl
- 4) ND_4Cl
- 5) D_2
- 6) HD

(the preparation of some of the compounds will require more than one reaction stage).

5. (9–10) A mixture of carbon oxide(II) and oxygen has a volume of 168 mL. After oxidation of the whole amount of carbon monoxide, the volume of the gas mixture became 140 mL. (The volumes of gases were measured at 1 atm and 273 K). Determine the amounts of gases in the initial mixture (in mL). What compounds are formed when the obtained carbon dioxide is bubbled into

a solution containing 0.15 g of sodium hydroxide? Calculate the masses of these compounds.

Write down the equations for the mentioned reactions.

6. (9–11) Among the substances mom used for cooking, Pete found a white powder, which he decided to analyze. First, he put some powder into a spoon and started to heat it carefully. The compound foamed and soon disappeared leaving the spoon empty. For the next experiment, Pete added some hydrochloric acid to the powder. This time, bubbles appeared even without heating and on heating, everything disappeared again leaving no residue. At the end of the process, a large cloud of white fumes was formed. Finally, Pete took again some of the powder and added a sodium hydroxide solution. Immediately he felt a pungent smell and, after heating, the spoon was coated by a white solid layer. What is the chemical formula of this solid? What is the chemical formula of the powder Pete analyzed? What for does this powder may serve in the kitchen? Write down the equations for the mentioned reactions.

7. (10–11) Roasting (burning in oxygen) of some mineral (a 5.52 g sample) gave 1.344 liters of a gas with a molecular mass of 64 and a solid residue. Dissolution of the solid residue in excess sulfuric acid gave a solution from which one can isolate two neutral salts of two different metals in a 2 : 1 molar ratio. An iron plate introduced into the solution becomes reddish, and when the reaction is over, the solution contains ions of only one metal. Determine the chemical formula of the mineral.

8. (10–11) A 4.1 g sample of an unsaturated hydrocarbon can add 8.0 g of bromine to give a dibromide. Determine the structure of the hydrocarbon if it is known that its hydrogenation and subsequent radical chlorination results in only one monochlorinated product.

9. (11) Organic chemists often use compounds containing a heavy hydrogen isotope — deuterium (D). Propose methods for synthesizing the following deuterated compounds:

- 1) $\text{CH}_3\text{CH}_2\text{OD}$
- 2) $\text{CH}_2\text{D}-\text{CH}_2\text{OH}$
- 3) CHD_2CHO
- 4) CD_3COOH
- 5) CH_3COOD
- 6) $\text{C}_6\text{H}_5\text{D}$

As the starting compounds, you may use any organic compounds containing no deuterium and heavy water D_2O (as the source of deuterium). Write down the equations for the required reactions.

Solubility of Ionic Compounds in Water

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Key: S=Soluble I=Insoluble D=Decomposes in water U=Compound does not exist or is unstable

Cation	Al	NH ₄	Sb	As	Ba	Bi	Cd	Ca	Cr	Co	Cu	Fe	Fe	H	Pb	Mg	Hg	Hg	Ni	K	Ag	Na	Sr	Zn
Anion	+3	+1	+3	+3	+2	+3	+2	+2	+3	+2	+2	+3	+2	+1	+2	+2	+2	+1	+2	+1	+1	+1	+2	+2
C ₂ H ₃ O ₂ ⁻¹	S	S	U	U	S	I	S	S	S	S	S	U	S	S	S	S	S	I	S	S	I	S	S	S
Br ⁻¹	S	S	D	D	S	D	S	S	S	S	S	S	S	S	I	S	I	I _a	S	S	I _b	S	S	S
CO ₃ ⁻²	U	S	U	U	I	U	I	I	U	I	I	U	I	S	I _a	I _a	I	I _a	I	S	I _a	S	I _a	I _a
ClO ₃ ⁻¹	S	S	U	U	S	U	S	S	U	S	S	U	U	S	S	S	S	S	I	S	S	S	S	S
Cl ⁻¹	S	S	S	D	S	D	S	S	S	S	S	S	S	S	I	S	S	I _b	S	S	I _b	S	S	S
CrO ₄ ⁻²	U	S	U	U	I _a	U	I	S	U	I	S	S	I	S	I _a	S	I _a	I _a	U	S	I _a	S	I _a	I _a
OH ⁻¹	I _a	U	U	U	S	D	I	I _a	I	I	I _a	I _a	I _a	H ₂ O	I _a	I _a	U	U	I	S	U	S	I	I _a
I ⁻¹	S	S	D	S	S	I	S	S	I	S	U	U	S	S	I _a	S	I _a	I _a	S	S	I	S	S	S
NO ₃ ⁻¹	S	S	U	U	S	D	S	S	S	S	S	S	S	S	S	S	S	D	S	S	S	S	S	S
O ⁻²	I _b	U	I	I	S	I	I	I	I	I	I _a	I _a	I _a	H ₂ O	I	I _a	I	I _a	I	D	I	D	I	I
C ₂ O ₄ ⁻²	I	I	I	U	I	D	I	I	S	I	I	S	I	S	I	I	I	I	I	S	I	S	I	I
PO ₄ ⁻³	I _a	S	U	U	I _a	I	I	I _a	I	I	I _a	I _a	I _a	S	I _a	I _a	U	U	I	S	I _a	S	I _a	I _a
SiO ₃ ⁻²	I	U	U	U	S	I	I	I _a	U	I	U	U	I	I	I _a	I _a	U	U	U	S	U	S	I _a	I _a
SO ₄ ⁻²	S	S	D	U	I _b	D	S	I _a	S	S	S	S	S	S	I	S	D	I	S	S	I	S	I	S
S ⁻²	D	S	D	I	D	I	I	I _a	I	I	I _a	I	I _a	S	I _a	D	I	I	I	S	I _a	S	I	I _a
SO ₃ ⁻²	U	S	U	U	I	U	I	I	I	I	U	U	I	S	I	S	U	U	I	S	I	S	I	I

I_a	Soluble in Acids	I_b	Slightly Soluble in Acids	H₂O	Produces water
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